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ASSESSMENT OF CABBAGE APHID DAMAGE IN COMMERCIAL BRUSSELS SPROUT CROPS

Contribution from the Conference of Entomologists, National Agricultural Advisory Service, compiled by A. H. Strickland of the Plant Pathology Laboratory, Harpenden, Herts

In the accurate measurement of crop losses attributable to aphids, damage to the host plant can be regarded as a product of pest density, pest activity, and plant growth—factors which are continually changing. Single observations, such as can conveniently be made on a large number of fields over a relatively short period in the course of a country-wide survey, cannot therefore lead to a very accurate estimate of damage over the country as a whole. Estimates of this kind can lead to an approximate assessment of yield reduction, provided a relationship has been established between pest density at a given time and the final yield of the host plant. A great deal of careful field experimentation is necessary before a relationship of this kind can be established, and the present paper summarizes the field work carried out with this end in view on the Cabbage aphid (*Brevicoryne brassicae* L.) during the 1951, 1952, and 1953 seasons.

MATERIALS AND METHODS

Early in 1951 a pilot scheme of field experimentation on Brussels sprouts and heading broccoli was drawn up, and two trials were carried out on sprouts (Cocayne Hatley, Bedfordshire, and Harlow, Essex) and one on broccoli (Westgate-on-Sea, Kent) during the growing season in that year. Eight plots of 200 plants each were set up at each site, individual plots being separated by three guard rows. Four plots were sprayed at fortnightly intervals with a strong TEPP solution to keep the plants as free from aphid attack as possible, and the other four plots remained untreated so that the aphids built up in the normal way. Aphid counts were made on all plots at regular intervals before every second spray application, using the " three-leaf " method already described (Church and Strickland, 1954). A supply of derris flea beetle dust was kept at hand for use on the unsprayed plots if necessary, and cabbage caterpillars were hand-picked if they became troublesome on these plots. Harvesting was carried out by professional pickers employed by the individual farmers concerned. They were told to reject all produce which they would normally reject as unmarketable, so that the final plot yield figures could be regarded as the total weight of marketable produce from the treated plants, which had been growing throughout the season virtually free from aphid attack, and from the untreated plants, which had been affected to a greater or a less extent by aphid damage.

When the results were assessed early in 1952, five conclusions were reached. First, the TEPP, although applied by knapsack sprayer at a concentration of 1 in 1,500 of the active material, with additional wetter, at fortnightly intervals throughout the growing season, did not give a satisfactory degree of aphid control. Secondly, there was an indication that the TEPP had had a growth-stimulant effect on the sprayed plants, which gave heavy yields early, and small yields late, in the season. This effect, if genuine, would bias correlations between yield and aphid density. Thirdly, plots of 200 plants were too large to spray by hand in the limited time available for the work. Fourthly, replications would have to be increased in future work ; and, finally, the broccoli experiment involved eleven visits to complete curd harvesting, compared with three and four visits to complete sprout picking.

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The experimental scheme was modified in 1952 by decreasing plot size to 100 plants and increasing the number of plots at each site from eight to twelve. There were three treatments: control plots, receiving no sprays; "aphid-free" plots, which received three applications of schradan (0·001 lb. of active material per application per plant) applied with a watering can and "dipper" to the roots of each plant separately: and the "tris" plots. The tris (tris-dimethylaminophosphonous anhydride) treatment was added as a check on a possible growth stimulant effect on the schradan-treated plants. The compound was thought to be insecticidally inactive but was known to have systemic properties (Heath, Lane, and Llewellyn, 1952). A dosage rate was computed such that each plant on the tris plots would receive as much organically-bound phosphorus as those on the schradan plots. By this means it was hoped that a comparison would be obtained from each site of the yields of the schradan-treated, aphid-free plots, the tris plots, which would have suffered a comparable aphid attack to the controls, and the control plots, on which aphids would have built up in the normal way. If any growth-stimulant action occurred due to organo-phosphate effects, the yields from the tris plots would presumably be greater than those from the control plots, in spite of very similar levels of aphid attack. As such, it would be possible to obtain a rough estimate of the effect of the stimulant action on yield, and allow for it in computing aphid effects.

This scheme was carried out at five sites during the 1952 season, while I investigated further modifications at a sixth site (Harlow, Essex). The Harlow experiment was laid down as a 5 by 5 Latin square in which the efficiency of two additional organo-phosphorus compounds as root-applied aphicides was compared with schradan at the rate used on the other five sites. The two compounds were demeton and "azide" (bisdimethylamino azidophosphine oxide), both applied three times at a concentration of 0·1 per cent active ingredient in ¼ pint of water per plant. This experiment was arranged on a basis of 64 plants per plot, in accordance with advice from Mr. Finch, Mr. North, and Mr. Grainger, of the National Institute of Agricultural Botany.

TABLE 1

SITE CHARACTERISTICS, 1951–53

County	Parish	Year	Soil Type	Soil *p*H	Sprout Variety	Planting Date
Bedford	Cocayne Hatley	1951	Clay loam	7·7	Cambridge No. 5	June 12
		1952	Clay loam	7·7	Cambridge No. 5	June 16
		1953	Clay loam	7·8	Ashwell	May 30
Berkshire	Longworth	1953	Clay	6·9	Not known	May 18
Essex	Harlow	1951	Clay loam	—	Cambridge No. 5	July 12
		1952	Clay loam	7·2	Sutton's Universal	June 16
Gloucester	Chipping Campden	1952	Chalk	—	Farmer's own	May 22
		1953	Chalk	6·9	Farmer's own	May 23*
Kent	Ramsgate	1952	Sandy loam	7·4	Cambridge No. 5	June 9
		1953	Sandy loam	7·8	Fillbasket	June 9
	Norton	1953	Sandy loam	5·9	Cambridge No. 5	June 10
Northumberland	Longbenton	1952	Clay loam	4·8	Cambridge No. 5	May 21
		1953	Clay loam	—	Cambridge No. 5	May 28
Warwick	Luddington	1953	Clay	—	Brown's Masterpiece	June 13
Worcester	Evesham	1952	Medium loam	7·0	Farmer's own	June 10
Yorkshire	Gateforth	1953	Medium loam	5·7	Farmer's own	April 29

*Chipping Campden, 1953, planting date given as the third week in May.

In 1953 the experimental scheme was modified in view of the results obtained at Harlow in the previous season, and the work involved was reduced to a minimum consistent with the results desired. The 64-plant plot was taken as the standard unit, and two treatments (controls, and aphid-free treated with azide at the same concentration used at Harlow in 1952) were replicated five times at each site.

Site details are given in Table 1. With two exceptions, experiments were carried out on commercially-grown sprouts. At Luddington a small area of sprouts was planted on the Experimental Station land and harvesting was carried out by the Station staff, who graded the produce into marketable and unmarketable material. At Longbenton in both years the experiment was carried out on the N.A.A.S. trial grounds and was harvested by N.A.A.S. staff.

Soil analyses were carried out at most of the sites prior to planting. The lime status was satisfactory at all sites except Longbenton, Gateforth, and Norton. Phosphate was high to very high at all sites except Cocayne Hatley, 1953, and potash was low only at Longbenton and Evesham. At both of these sites plot yields were on the low side, accentuated by late planting and a bad tilth at Evesham and drought and Club Root at Longbenton. Yields at Ramsgate were also rather poor, though the grower did not comment on this, apart from saying that they were normal for the district.

There was considerable variation in planting date from site to site and from year to year. Drought conditions in June 1951 resulted in a poor stand at Cocayne Hatley, where 400 plants were replaced on June 27, and planting was delayed until July 12 at Harlow. In 1953 growing conditions were ideal early in the season and all sites had been planted by the middle of June. The experiments therefore relate to good and poor growing seasons, cultivation by large and experienced growers as well as on a small scale, a fair range of soil types and conditions, and a good selection of popular commercial sprout varieties.

GROWTH OF THE HOST PLANTS

Brussels sprout plants are generally grown in a small seedbed and planted out in the field at one-yard spacing when 4–6 inches in height at the 5–6 leaf stage. After an establishment period, which may last for up to two weeks dependent on weather conditions, the plants begin to grow away quickly. Height increases fairly constantly over the first three months in the field, and then the rate decreases, until the height becomes virtually static with the onset of winter. Routine height measurements were made at several sites in 1952, and the results from three of them are shown in Fig. 1, in which the mean height of the control plot plants is given in relation to that of the schradan-treated plants. At Harlow the treated plants were slightly, but not significantly, taller than the control plants—an effect which might have been due to slight stunting from the heavy aphid attack which developed at this site. At Ramsgate the control plants were slightly taller than the treated plants over most of the season, and the same result was observed at Chipping Campden.

Leaf counts were made at regular intervals at Harlow in 1952. One month after planting out, the plants under all five treatments carried an average of 12 expanded leaves. After seven weeks there was a mean of 26, and after ten weeks a mean of 37 expanded leaves per plant. There were no differences between treatments, although it was observed that the leaves on heavily-attacked plants on the control and tris plots were rather smaller than on plants which were not attacked.

After the final sprout harvest at several sites stalks were severed at ground level, bulked for each plot, and weighed. From data obtained at Chipping Campden, Ramsgate, and Harlow in 1952, at Longbenton in both years, and at Gateforth in 1953, it was clear that stalk weight differed significantly between treatments and was associated with different intensities of aphid attack. It was also evident that stalk weight is closely correlated with yield of marketable sprouts: an analysis computed on the available data gave a correlation coefficient of + 0·504 with 58 degrees of freedom when differences due to variation between sites were eliminated. The within-site regression of yield on stalk weight was + 0·77 ± 0·06, which is significant at a probability of 0·001.

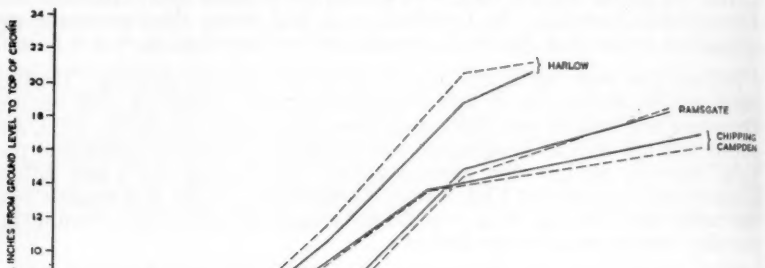
MEAN HEIGHT OF PLANTS, INCHES FROM GROUND LEVEL TO TOP OF CROWN
WEEKS AFTER PLANTING OUT
HARLOW
RAMSGATE
CHIPPING CAMPDEN
Plants on Control plots
Plants on Schradan-treated plots

Fig. 1. Mean height of plants on the control and schradan-treated plots at Harlow, Ramsgate and Chipping Campden, 1952.

From these results it seems as if height and leaf number do not give a particularly good indication of the normal growth of a sprout plant. Since stalk weight clearly gives a good indication of growth, the inference is that plants which have been severely attacked by aphids have thinner and weaker stalks than unattacked plants. A girth measurement might therefore give a good indication of growth and yield. It is clear that aphid damage affects the whole physiology of the sprout plant and is not simply a matter of direct injury to a few sprout buds, or of physical contamination by large numbers of individual aphids.

YIELD OF MARKETABLE PRODUCE

Yields of sprouts and tops, corrected throughout to terms of plots of 100 plants, are given in Table 2, together with the standard errors appropriate to the sprout data. In three cases (Cocayne Hatley, Longbenton, and Ramsgate) there was some phytotoxic damage, due probably to drought conditions shortly after the first application of schradan and tris. Some gaps resulted from this damage, and these have been allowed for in computing Table 2.

There are several points of interest in this table. Yields vary considerably from one year to the next on the same farm (Chipping Campden, Harlow, Longbenton). They also differ considerably from one district to another in the same

year. It is clear, for instance, that the Ramsgate grower is satisfied with a yield of about 1 lb. per plant (43 cwt. per acre), whereas a crop of this size was thought scarcely worth the trouble of picking at Harlow in 1951.

TABLE 2

YIELDS OF MARKETABLE SPROUTS AND TOPS IN LB. PER 100 PLANTS

Site	Year	Controls		Treated		Tris		S.E. for
		Sprouts	Tops	Sprouts	Tops	Sprouts	Tops	Sprouts
Cocayne Hatley ..	1951	157	—	164	—	—	—	4·8
	1952	133	28	146	29	—	—	7·4
	1953	147	—	154	—	—	—	11·7
Chipping Campden ..	1952	239	32	238	30	253	32	10·5
	1953	174	16	199	18	—	—	18·8
Evesham	1952	94	—	119	—	105	—	7·5
Harlow	1951	99	38	103	49	—	—	2·9
	1952*	134	36	195	42	171	38	5·0
Gateforth	1953	161	—	190	—	—	—	5·3
Longbenton	1952	147	24	148	24	111	20	9·3
	1953	225	—	244	—	—	—	8·2
Longworth	1953	245	—	289	—	—	—	7·0
Luddington	1953	161	36	166	34	—	—	3·6
Norton	1953	108	—	136	—	—	—	13·8
Ramsgate	1952	94	35	105	38	97	39	13·0
	1953	100	—	108	—	—	—	5·7

*The demeton plots gave 211 lb. of sprouts and 41 lb. of tops, and the azide plots 206 lb. of sprouts and 41 lb. of tops.

The 1953 season was a better one for sprout growing than 1952, and treated plot yields at three of the four sites on which experiments were carried out in both years reflect this. There was, in fact, a glut of sprouts late in 1953, prices dropped, and tops were left until the market recovered. The weather remained mild, and by the time tops were commercially worth picking many had rotted, so that it was possible to cut and weigh them on only two sites.

A further point of interest in Table 2 is that the yield differences between the control and treated plots at Chipping Campden, Longbenton, and Ramsgate in both years, and at Cocayne Hatley, Norton, and Luddington in 1953, were not significant. So, quite apart from differences in aphid density between treatments, there is no evidence of a growth-promoting effect from the schradan and azide used in these experiments.

CABBAGE APHID DENSITY, 1952–53

It was intended that aphid counts should be made at each site on the same day, or at most within two or three days of each other, so that comparisons could be made of the behaviour of the aphid in different parts of the country. Differences in planting date, varying weather, and pressure of advisory duties on the part of individual collaborators, combined to make this impracticable. Results have therefore been tabulated as referable to periods of ten days or less, and comparisons between sites should be made with this fact in mind.

Aphid density differed considerably between months, years, and sites. In 1951 peak density was reached at Harlow late in September, and at Cocayne Hatley in the middle of October. In 1952 it was reached at both these sites towards the end of August, and in 1953 at Cocayne Hatley at the end of September. Although it is not possible to forecast with any accuracy when the peak is likely to occur at any given site, it does seem from Table 3 that populations tend to build up until the third or fourth week in September and then decrease.

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At five of the sixteen " site-years " aphid density exceeded a log value of 2·00 per sample during the growing season—a level at which many of the control plot plants would be classified as severely infested under the category sampling method of Empson (1952). This level was approached, and probably exceeded, at Evesham and Chipping Campden in 1952. In at least nine of the experiments aphid density on the control plots remained low throughout the season.

TABLE 3

MEAN LOG (N+1) APHIDS PER THREE-LEAF SAMPLE ON THE CONTROL PLOTS

Site	Year	Periods during which Samples were taken										
		June	July			August			September		October	
		20–30	7–11	17–22	23–31	1–11	15–25	2–8	13–19	20–30	1–4	11–20
Cocayne	1951	—	0·00	—	0·30	—	1·32	—	—	—	—	1·71
Hatley	1952	0·01	0·71	—	2·47	2·71	2·71	2·24	1·69	—	—	0·36
	1953	—	—	—	0·12	—	1·09	—	—	1·42	—	—
Chipping	1952	0·08	0·54	0·79	—	1·19	1·63	1·76	1·97	0·92	—	0·28
Campden	1953	—	0·00	—	—	0·33	—	—	1·41	—	1·19	0·06
Evesham	1952	0·88	1·92	—	1·97	—	—	0·51	1·50	—	—	—
Gateforth	1953	—	—	—	0·80	—	1·28	—	—	1·32	—	0·40
Harlow	1951	—	—	—	0·02	0·31	1·33	1·75	2·67	2·78	—	1·30
	1952	—	1·74	1·89	2·89	2·95	3·30	3·11	1·15	—	0·93	0·24
Longbenton	1952	0·00	0·20	0·22	—	0·35	1·16	1·86	1·79	1·71	—	1·25
	1953	—	0·28	—	—	—	0·55	1·14	—	—	1·21	—
Longworth	1953	0·06	—	—	1·70	—	2·40	—	—	—	—	—
Luddington	1953	0·01	—	—	—	1·50	1·24	0·82	—	—	—	—
Norton	1953	—	1·40	—	—	1·60	—	2·28	2·75	—	1·60	—
Ramsgate	1952	0·09	0·83	0·76	—	1·34	1·25	1·54	1·11	1·15	—	0·89
	1953	—	1·25	—	—	0·94	—	1·74	1·78	—	—	—

If the information on planting dates given in Table 1 is considered in relation to the aphid count data in Table 3, it is apparent that the sites can be divided into two groups : those at which the density of aphids on the control plots reached a level of about 2·00 per sample early in the season and generally increased to a higher level over the next few weeks, and those at which the density either never reached this level, or did not reach it until the plants had been growing away under rather small infestations for three or four months. Reference to Table 2 shows that the greatest differences between the control and aphid-free plot yields were obtained at Evesham and Harlow in 1952 and at Longworth, Norton, Gateforth, and Chipping Campden in 1953. At the first three of these sites aphids built up early in the season, whilst Norton was the only site in 1953 at which density is known to have exceeded 2·00 per sample over a period of at least three weeks.

TABLE 4

MEAN LOG : (N+1) APHIDS PER SAMPLE PER TREATMENT, 1952 AND 1953

Sites and Years	Controls	Schradan	Tris	Demeton	Azide
1952, all sites except Harlow.	1·26 ± 0·14	0·68 ± 0·09	0·84 ± 0·22	—	—
1952, Harlow only..	2·09 ± 0·37	1·05 ± 0·27	1·68 ± 0·32	0·59 ± 0·21	0·69 ± 0·24
1953, all sites ..	1·13 ± 0·14	—	—	—	0·22 ± 0·06

Aphid density on the treated plots was always lower than on the controls and the tris plots. At Evesham, for example, tris plot density was recorded as 0·54 on the same day as a control plot record of 0·92. At Harlow, a tris plot

record of 2·70 was obtained at the same time as a control record of 2·95. At three other sites it was clear that tris applications had adversely affected the aphids. A summary of the effect the treatments had on aphid density is given in Table 4, which has been drawn up from the data from each site obtained during the second, third, and fourth, complete months after planting in an attempt to strike an overall seasonal mean for each treatment. From these results it is plain that population density on the control plots over the season as a whole was significantly higher than on the schradan, demeton, and azide plots. Differences between the control and tris, and tris and schradan, plots were not, however, significant.*

CABBAGE APHID DENSITY IN RELATION TO YIELD

In comparing yields from the treated and control plots in relation to the estimates of aphid density made on each plot, a series of regressions has been computed, and the results are given in Tables 5, 6, and 7, and Figs. 2, 3, and 4. Individual plot values have been used in these analyses. For example, plot 4 at Cocayne Hatley in 1952 yielded 132 lb. of marketable sprouts. The highest level of density recorded on this plot within eight weeks of planting was 2·74 aphids per sample, and the highest level over the whole season was 2·86.

Table 5 gives the values of the regression coefficients for yield of sprouts on peak aphid density at eight weeks and over the whole season for all sites over the three years. The 1951 results may have been affected by TEPP stimulation, and may therefore not give true pictures of aphid effects.

TABLE 5

INDIVIDUAL SITE REGRESSION COEFFICIENTS FOR YIELD OF MARKETABLE SPROUTS ON LOG (N + 1) APHID DENSITY AT EIGHT AND TWELVE OR MORE WEEKS AFTER PLANTING

Site	Year	Degrees of Freedom	Coefficient at Eight Weeks	Coefficient at Seasonal Peak
Cocayne Hatley	1951	6	−19 ± 12	− 7 ± 11
	1952	6	−33 ± 5*	−27 ± 12
	1953	8	+77 ± 65	−12 ± 17
Chipping Campden	1952	10	− 0 ± 13	+ 4 ± 1*
	1953	8	+47 ± 64	−53 ± 36
Evesham	1952	10	−18 ± 10	−21 ± 25
Gateforth	1953	8	−25 ± 10*	−18 ± 5*
Harlow	1951	2	− 4 ± 13	+ 5 ± 13
	1952	23	−57 ± 8*	−26 ± 3*
Longbenton	1952	10	− 1 ± 51	+18 ± 44
	1953	8	−20 ± 25	−12 ± 10
Longworth	1953	8	−19 ± 7*	−20 ± 5*
Luddington	1953	8	−17 ± 9	−10 ± 8
Norton	1953	8	−21 ± 14	−11 ± 10
Ramsgate	1952	10	− 7 ± 16	−45 ± 92
	1953	8	− 5 ± 7	− 6 ± 5

*Significant at P = 0·05.

Of the thirty-two coefficients in Table 5, five are positive and twenty-seven are negative. Of the five positive values, only one (Chipping Campden 1952) is significant. This site had a rather light aphid attack and there was no difference between control and treated plot yields. Seven of the negative values are

*With regard to the apparently insecticidal action of tris, detailed tests have recently been carried out by Dr. W. A. L. David (A.R.C. Unit of Insect Physiology). David used samples of tris from the bulk consignment used in the 1952 trials, as well as the pure, re-distilled compound. He found no evidence of direct insecticidal action with either (*in lit.*).

significant, and five of these refer to sites at which moderate–large aphid populations developed. There is a clear trend towards a negative relationship between yield and aphid density, and the two significant coefficients from the Gateforth data indicate that quite low densities may have an adverse effect on yield.

Regression and correlation coefficients have been computed for the 1952 and 1953 data, using pooled sums of squares and eliminating differences due to variation between sites, and these are given in Table 6. As might be expected, the seasonal peak populations are rather more closely correlated with yield than those recorded earlier in the season. The regressions for these two population estimates are, however, very similar. Both are subject to large errors and do not differ significantly at the 5 per cent point. It is of some interest that the values for 1952 are greater than those for 1953, an indication of the higher populations and greater range of yields in that year.

TABLE 6

REGRESSION AND CORRELATION COEFFICIENTS FOR ALL SITES, ELIMINATING BETWEEN-SITE VARIATION

Year	D.F.	Coefficients at Eight Weeks		Coefficients at Seasonal Peak	
		Regression	Correlation	Regression	Correlation
1952	73	−29·21 ± 6·03	−0·495	−20·10 ± 3·61	−0·546
1953	70	−15·61 ± 5·21	−0·337	−14·97 ± 3·61	−0·445

The data from which these overall regression coefficients were computed are given in graphical form in Figs. 2 and 3. Fig. 2 shows the individual plot values for all sites and years referable to the eight-week data in relation to yield of marketable sprouts, along with the two regression lines for years eliminating site

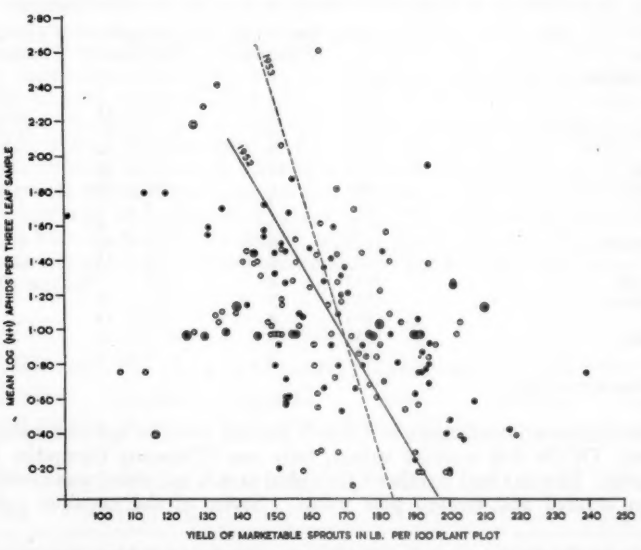

Fig. 2. Regressions of yield of marketable sprouts on Log (N + 1) aphid density per three-leaf sample at peak level reached within eight weeks of planting out. All sites, 1952 and 1953. 1952 b = 29·21 ± 6·03 (73 d.f.) 1953 b = −15·61 ± 5·21 (70 d.f.)

variation, the points representing deviations from the mean values appropriate to each site. Fig. 3 shows the aphid and yield values referable to the seasonal peak twelve or more weeks after the plants had been set.

Certain values have been ringed on the diagrams. These refer to plots which were either infected with Club Root or adversely affected by tris applications during drought periods—in other words, plots on which the yield was known to have been adversely affected by factors other than direct aphid damage. Twelve of the points refer to Longbenton in 1952, where both tris damage and Club Root occurred. As can be seen from Table 2, the tris plot yields at this site were much smaller than those from the control and schradan plots, yet aphid density never reached the level found on the controls. A further two of the points refer to Norton, where Club Root was severe on one treated and one control plot. The yield of the treated plot was 72 lb., compared with a mean of 153 lb. from the other four treated plots, and the yield of the control plot was 83 lb., compared with a mean of 115 lb. from the other controls. Aphid density was considerably greater on the control than on the treated plot, and it is clear that a severe Club Root infection can substantially mask aphid effects.

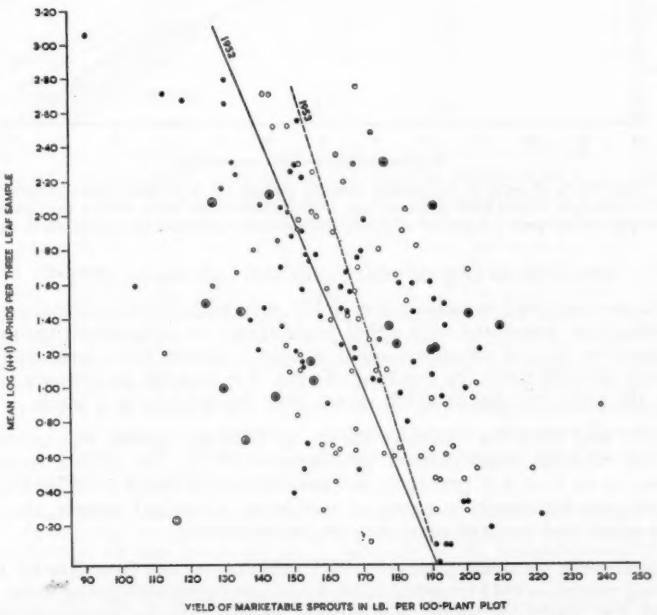

Fig. 3. Regressions of yield of marketable sprouts on Log (N + 1) aphid density per three-leaf sample at peak level over the season as a whole, usually reached about twelve weeks after planting out. All sites, 1952 and 1953.

1952 $b = -20{\cdot}10 \pm 3{\cdot}61$ (73 d.f.) 1953 $b = -14{\cdot}97 \pm 3{\cdot}61$ (70 d.f.)

A further analysis has been carried out on the data from all sites for 1952 and 1953 in which both site and year variation has been eliminated. The overall regression coefficients for yield on aphid density are $-20{\cdot}87 \pm 3{\cdot}93$ for the eight-week data, and $-17{\cdot}36 \pm 1{\cdot}44$ for the seasonal peak data, both with 144

degrees of freedom. These coefficients are shown graphically in Fig. 4 and indicate that an infestation developing early in the season may have a greater effect on yield than one not developing until the plants have been growing away for a period of months. The coefficients do not, however, differ significantly.

Fig. 4. Regressions of yield of marketable sprouts on Log (N + 1) aphid density per three-leaf sample at (A) eight weeks after planting out, and (B) twelve or more weeks after planting out (seasonal population peak), together with the appropriate 5 per cent fiducial limits in each case.

ESTIMATES OF LOSS OF YIELD, ENGLAND AND WALES, 1952–53

If the seasonal peak regression line in Fig. 4 is taken as indicating the order of yield reduction associated with aphid populations on commercial sprout fields in September, then, if the mean aphid density is known for a large number of randomly selected fields for this time of year, it is possible to estimate approximately the yield loss due to aphid attack over the country as a whole.

In 1952 and 1953 the extensive survey of Cabbage aphids was carried out, using the ranking terms defined by Empson (1952). In 1953 a number of observers in six N.A.A.S. provinces co-operated in an attempt to define Empson's categories approximately in terms of aphids per three-leaf sample, the aphids being washed and counted accurately in the laboratory.

Records were obtained relative to 831 samples, results from five of the co-operating provinces (541 samples) being fairly consistent and giving mean values of 3, 30, 130, and 1,390 aphids per sample, respectively, for plants classified as "Clean", "Slightly", "Moderately", and "Severely" infested in the field. The sixth province submitted values of 10, 420, 4,430, and 6,410 aphids per sample, based on 290 samples.

Using values for each set of fields appropriate to the province or, where certain provinces which did not co-operate in this experiment are concerned, using the average values 3, 30, etc., given above, each field surveyed in 1952 and 1953 has been given a numerical value, which has been transformed into terms of mean log aphids per sample. These estimates of peak aphid density on

a substantially random sample of unsprayed commercial sprout crops in September 1952 and 1953 are given in Table 7.

TABLE 7

ESTIMATES OF PEAK APHID DENSITY ON COMMERCIAL SPROUT CROPS, 1952–53

Counties Surveyed	Year	Number of Fields Examined	Estimated Mean Log (N+1) Aphids per Sample
Cumberland, Durham, Northumberland and Westmorland	1952	21	1·61
	1953	19	1·30
Yorkshire and Lancashire	1952	19	2·16
	1953	14	2·00
Anglesey, Caernarvon, Denbigh, Flintshire, Cheshire and North Staffordshire	1952	19	1·37
	1953	12	1·40
Warwick, Worcester, Wiltshire and Gloucester	1952	35	2·25
	1953	24	1·72
Glamorgan and Monmouth	1952	10	1·13
	1953	10	1·14
Berkshire, Buckingham and Middlesex ..	1952	14	1·43
Hampshire	1952	6	1·24
Kent	1952	20	1·81
	1953	20	1·83
Bedfordshire	1953	8	2·07
Annual means for all counties	1952	144	1·77
	1953	107	1·64

If the two mean values of 1·77 and 1·64 at the bottom of Table 7 are taken as giving very approximate estimates of the average aphid density on untreated crops in the counties surveyed, reading off from the seasonal peak regression line in Fig. 4 it appears that yield was reduced from 82 to 68·5 cwt. of marketable sprouts per acre in 1952, and from 82 to 69·5 cwt. per acre in 1953. These estimates amount to 17 and 15 per cent of the crop, respectively, and it must be emphasized that they are subject to large errors. If the mean values from the untreated experimental plots for the period September 13—October 8 are taken as giving a more accurate estimate of overall density, values of 1·54 and 1·68 are obtained for 1952 and 1953 (omitting Longworth and Luddington) respectively. These values indicate losses of 12 and 13 cwt. per acre, or approximately 15 per cent of the crop in each year. Even if these two independent estimates are inaccurate by as much as a factor of two, it is abundantly clear that Cabbage aphid is a serious pest of Brussels sprouts and warrants detailed ecological investigation with a view to natural control.

The Conference of Advisory Entomologists would like to thank those farmers who co-operated in allowing complex field experiments to be carried out on a valuable crop. Acknowledgments are also due to Mr. A. L. Abel, Dr. R. M. Greenslade and Dr. G. S. Hartley, of Pest Control Ltd., for valuable advice on the root application of systemic insecticides and for supplying some of the chemicals used in the 1952 and 1953 trials. Finally, the compiler would like to thank Mr. B. M. Church for advice on some of the statistical problems associated with the plot and survey results.

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CARROT FLY AND "CANKER" OF PARSNIPS IN THE SOUTH-WEST

by L. E. W. STONE

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Over the period 1949–53, while Collingwood and Croxall (*Plant Pathology*, 1954, 3, 99–103) were working on the problem of Carrot fly injury and "canker" in parsnips in the West Midland Province, similar investigations were in progress in the South-West. Detailed observations were made on holdings at Frenchay, near Bristol, where the soil was a light sandy loam and a heavy population of the Carrot fly, *Psila rosae* F., had been built up as a result of intensive growing of susceptible crops. This paper summarizes the results over the five years, with special reference to the suppression of "canker" by control of Carrot fly. The term "canker" is here used to denote rotting of a whole or part of the shoulders of the roots, however caused, and by "Carrot fly injury" is meant mining by Carrot fly larvae. The conflicting views of previous workers on the etiology of "canker" have been discussed by Collingwood and Croxall in this Journal (*ibid.*), and references to the literature are therefore not repeated.

PRELIMINARY OBSERVATIONS, 1949 AND 1950

In 1949 a block of fifteen 10-yard rows of parsnips, variety Lisbonnais, were dusted with 2½ per cent BHC dust on May 12 and 30 to control the first generation of Carrot fly. The dust was applied round the crowns with a bellows-type duster at the rate of ½ oz. per row. Samples of 100 roots lifted at random from the dusted block, and from an adjacent untreated area, in late September, indicated that about 60 per cent of the treated parsnips were free from canker, while in the adjacent untreated area only about 32 per cent were free. The extent of canker on all the affected roots was slight, and it took the form of a darkening of the tissue surrounding the mines made by the Carrot fly larvae. 1949 was a dry year, and the total rainfall in the area for the months of June to August inclusive was only 3·4 inches.

In 1950, strips of parsnips of the same variety on the same holding were dusted with 2½ per cent BHC dust, and with 5 per cent DDT dust, on May 22 and June 3, in the same manner as in 1949. In this year Carrot fly attack was very severe, and with much higher rainfall than in 1949 (12·8 inches for June–August inclusive) there was extensive and about equal development of canker in both the dusted and the control strips. All the canker was associated with the mines of the larvae.

VARIETY TRIALS IN 1951

In 1951 records were taken from trials designed by Mr. R. C. Twyman, Horticultural Advisory Officer of the N.A.A.S. at Gloucester, and laid down by his staff at Frenchay. The trial included four varieties, with four treatments and two sowing dates. Eight plots were sown in two blocks of four. Each plot contained a double row of each variety, put down in random order. The treatments were applied to whole plots, one block of which were sown in mid-March and the other about a month later. The four treatments were: (*a*) normal cultivations; (*b*) roots earthed up; (*c*) no cultivation after thinning, apart from pulling large weeds by hand; and (*d*) dusting against Carrot fly, with normal cultivations. In the dusting treatment 2½ per cent BHC dust was used in the

manner already described; four dustings were given in May and June against the larvae of the first generation, and three further dustings in August and September against those of the second generation.

On September 7, 40 roots per variety from each plot were lifted and examined. From the dusted plots, 90 per cent of the crowns were free from Carrot fly injury and no canker had developed on them. From the plots with all other treatments, 50 per cent or more of the crowns were injured by the larvae, and canker had already begun to appear on them. All the remaining roots were lifted early in November, and the numbers showing canker were recorded. The method of angular transformation was used in the statistical examination of the percentages. Mean percentages (calculated from the transformed values) are given in Table 1, but all tests of significance must be made on the figures expressed in degrees.

Of the varieties included in the trial, Yates Selected showed significantly more canker than the others. No treatment other than dusting had any significant effect. The dusting was in fact more beneficial than is indicated by the figures in Table 1, as on dusted roots the damage was confined mainly to discoloration of the tissue round the mines made by the larvae, whereas with the other treatments the damage was often very severe, some of the crowns being quite rotten. The canker developed very rapidly during September following heavy rainfall (4·6 inches) in August. No tainting was detected in samples from dusted plots in this trial.

TABLE 1

INCIDENCE OF CANKER IN PARSNIP VARIETY TRIALS, 1951 AND 1952

	Proportion of Roots showing Canker			
	in November, 1951		in October, 1952	
	degrees	*per cent*	*degrees*	*per cent*
Varieties				
Yates Selected	54·2	66		
Yates Evesham			75·4	94
Tender and True	48·3	56		
Syston's Intermediate			65·2	82
The Student	45·3	50	59·3	74
Lisbonnais	46·3	52	64·5	81
Significant Difference (P = 0·05)	5·7	—	10·5	—
Treatments				
Normal cultivation	55·5	68	75·1	93
Earthed up	58·1	72	77·5	95
No cultivation after singling	51·4	61	67·1	85
Dusted	27·4	21	33·2	36
Significant Difference (P = 0·05)	21·0	—	24·5	—

VARIETY TRIAL IN 1952

In 1952 records were again taken from variety trials at Frenchay. In this year the varieties were Yates Evesham, Syston's Intermediate, The Student and Lisbonnais. The treatments were the same as in 1951, except that a 1·6 per cent *gamma*-BHC dust was used instead of the crude 2·5 per cent BHC material. Seven dustings were given in May and June against the first generation of Carrot fly, and three further dustings in August against the second generation. Ten roots per variety from each plot were lifted at random and examined on October 8. The data were treated as before, and the results are given in Table 1.

In 1952 the Yates strain was again the most susceptible variety, although it just failed to be significantly more so than Syston's Intermediate at the 5 per cent probability level. Again dusting was the only treatment that significantly reduced the incidence of canker. Canker became severe following the heavy rain (8·5 inches) in August and September.

In the thirty-two samples of 10 parsnips taken from the plots in this year counts were made both of the number of roots mined by Carrot fly larvae and of the number showing canker. There was a very high degree of correlation between Carrot fly attack and incidence of canker ($r = 0{\cdot}925$ ($P < 0{\cdot}01$)).

TRIALS IN 1953

Three varieties and five treatments were included in the variety trial at Frenchay in 1953. The varieties were Magnum Bonum, Lisbonnais and Syston's Intermediate. The treatments were : (*a*) control ; (*b*) spraying once with 0·1 per cent DDT against the first generation of the Carrot fly ; (*c*) spraying twice with the same material, once against each generation ; (*d*) seed treatment with a mercury-BHC compound at 1 oz. per lb. ; and (*e*) dusting with 1·6 per cent *gamma*-BHC. A dressing of 1 oz. of dust per 5-yard row was applied at the first emergence of flies in mid-May, again after thinning in early June, and once in late July. There was heavy rain in July and August (11·2 inches in the two months) and much canker developed. When samples were lifted in October, there was no significant difference between the incidence of canker in the three varieties. Canker was present on over 90 per cent of the roots subjected to all treatments except dusting ; dusted roots had 63 per cent canker.

An experiment was carried out on the variety Lisbonnais at Frenchay in 1953 to test the effect of seed dressings. 50 per cent *gamma*-BHC, 50 per cent dieldrin and 40 per cent aldrin were each used at 4 oz. per pound of seed, with flour paste as a sticker. There were four replications of each treatment and control in a randomized block layout. There was little or no first generation attack on the site, but a heavy attack by second generation flies developed. Thirty roots were lifted at random from each plot in November. The proportions of clean crowns are given in Table 2, which also gives germination figures, determined by incubating 100 seeds per treatment on damp filter paper at 20° C.

TABLE 2

EFFECT OF SEED DRESSINGS ON INCIDENCE OF CANKER, 1953

Treatment (4 oz. per lb. of seed)	Germination *per cent*	Proportion of Clean Crowns *degrees*	*per cent*
Aldrin, 40 per cent	55	38·3	38
Gamma-BHC, 50 per cent	53	37·6	37
Dieldrin, 50 per cent	68	34·7	33
Untreated control	71	19·0	11
Significant Difference ($P = 0{\cdot}05$)		13·9	

Although all the seed treatments gave significantly better results than the controls, they did not give a commercial control, as only about 40 per cent of the crowns were clean at lifting.

EFFECT OF DATE OF SOWING

As in 1951, all the variety trials included sowings on two dates. The second sowing was always early enough to produce a plant by the time the first

generation of Carrot flies emerged. Both sowings were therefore exposed to both generations of flies. The mean percentages of roots showing canker in each year were as follows :

	Early Sowing	Late Sowing
1951..	49·5	59·0
1952..	76·0	74·0
1953..	94·0	85·3
All years	73·2	73·1

It is evident that at Frenchay there was no general benefit from late sowing.

RELATION BETWEEN CARROT FLY INJURY AND CANKER

Every individual parsnip among the samples from the variety trial at Frenchay in 1953 was assessed for both Carrot fly injury and canker. The categories for Carrot fly attack were : " Absent ", " Slight ", " Moderate " and " Severe " ; judgment being made by eye according to the number of mines visible. Canker was assessed similarly. " Slight " canker signified slight discoloured areas only, almost invariably round Carrot fly mines ; " Moderate " indicated more extensive damage ; and " Severe " meant decay affecting half or more of the crown. The contingency table below shows the number of roots (out of a total of 300) falling into each category for Carrot fly injury and canker.

		CANKER			
		Absent	Slight	Moderate	Severe
CARROT FLY INJURY	Absent	15	—	—	—
	Slight	14	33	—	—
	Moderate	—	22	55	—
	Severe	1	3	51	106

The dependence of canker upon Carrot fly injury at Frenchay in 1953 is obvious from the above without further analysis of the data. Similar tables were obtained from a like number of roots lifted in variety trials at Cheltenham and Mickleton in Gloucestershire, on much heavier soil. In no case was canker found to be present in the absence of Carrot fly mines, and this was our experience throughout the trials. Of the very many roots examined in all the years, only two or three were found in which canker was present in the absence of clearly discernible Carrot fly damage. Patches of rot, resembling canker, were often found deep down on the roots of the parsnips, again always in association with Carrot fly damage. Search for the eelworm parasite, *Ditylenchus dipsaci*, was often made, but none was found.

The form of canker encountered in these trials was clearly initiated by Carrot fly attack, and its subsequent development appeared to be influenced by many factors, perhaps the most important of which was summer rainfall. Collingwood and Croxall (1954) had much the same experience in their trials in the West Midlands, and it is evident that much of the so-called " canker ", both in that area and in the South-West, may be prevented by control of Carrot fly. Although the use of dusts of low *gamma*-BHC content materially reduces the incidence of canker, it is clear that under the conditions applying at Frenchay and elsewhere in the West Country, dusting would have to be both frequent and heavy to effect a commercial control in wet seasons.

I wish to thank Mr. L. N. Staniland for his advice and encouragement in this work, and other colleagues in the N.A.A.S. Entomology Department at Bristol, notably Miss A. N. F. Pain, for assistance in the field.

RESISTENTA—AN EELWORM RESISTANT CLOVER

by E. B. BROWN

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In Sweden some new varieties of late-flowering red clover, notably Merkur and Resistenta, have shown considerable resistance to attack by *Ditylenchus dipsaci* (Kühn) Filipjev. (Akerberg and Bingefors, *Lantmannen*, 1947, **31**, 83–5; Bingefors, *Svensk Frötidning*, 1948, **17**, 2–6). One of these varieties, Resistenta, was compared with a good English strain of broad red clover on two infested fields in the eastern counties of England in 1950–51. Examination of small samples showed no eelworm infestation on the seed of either.

At Braughing in Hertfordshire, three plots each of Resistenta (at the rate of about 8½ lb. of seed per acre) and broad red clover (at 10 lb. per acre) were sown on April 20, 1950, under spring barley, in a field where both clover rot and clover eelworm were prevalent in the last clover crop, taken in 1947–48. The plots were arranged alternately and measured 14 feet by 150 yards. The condition of the clover in all the plots was good after harvesting the barley, but it deteriorated during the winter. Eelworm and clover rot were present in all the plots, but by the following May there was considerable recovery, especially in the Resistenta. The mean numbers of plants in ten 2-foot square random quadrats per plot on June 13 were as follows :

Broad Red Clover	*Resistenta*
$4{\cdot}2 \pm 6{\cdot}8$; $7{\cdot}1 \pm 8{\cdot}5$; $6{\cdot}2 \pm 5{\cdot}6$	$21{\cdot}9 \pm 7{\cdot}9$; $21{\cdot}3 \pm 8{\cdot}3$; $23{\cdot}0 \pm 7{\cdot}6$

The stand of broad red clover was so poor that had it been a commercial crop it would probably have been ploughed up, whereas the Resistenta was a normal stand.

At Haddenham in Cambridgeshire, six similar plots were sown with the same stocks of Resistenta and broad red clover seed (at the rate of 8 lb. per acre for both) on March 24, 1950, in a field in which a severe attack of eelworm on clover had occurred in 1948. This field was ploughed very deeply in the winter of 1949–50 and was drilled with spring barley. After harvest and through the ensuing winter the stands of both clovers remained equally good, with the broad red taller than the Resistenta. On May 24, 1951, eelworm patches were present in all the plots, but in the Resistenta they were small (under 12 inches in diameter), few in number (with a mean of about six per plot), and the plants were recovering. In the broad red the patches were much larger, with a mean of about twelve per plot over a yard in diameter, and it was noteworthy that the patches on the edges of the plots did not extend into the adjacent Resistenta, but remained roughly semi-circular in outline (Plate II, 1).

It is possible that similar results might have been obtained in these trials if an English late-flowering variety had been substituted for the Resistenta, as the late-flowering red clovers are generally considered to be less susceptible to eelworm than the broad reds. The trials did indicate, however, that Resistenta can be grown successfully under English conditions, and that it can give a better stand of plants than broad red on infested land.

BROWN ROT CANKERS IN MERTON WORCESTER APPLE (see p. 139)

Conidial pustules of *Sclerotinia fructigena*.

On spur cankers. On branch cankers.

PLATE I

AN EELWORM RESISTANT CLOVER (*see p. 122*)

1. Part of plots at Haddenham in May 1951, showing eelworm patch in broad red clover limited by margin of the adjacent Resistenta.

STEM AND BULB EELWORM ON POTATOES (*see pp. 139–40*)

2. Potato haulm infested with *Ditylenchus dipsaci*, showing swelling, distortion and bunched appearance of foliage.

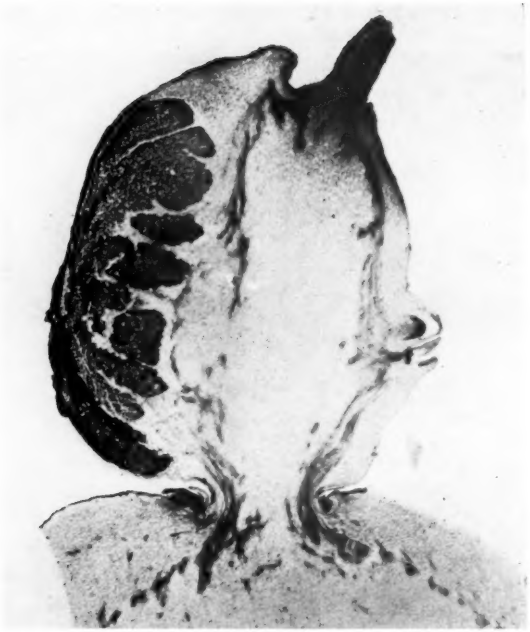
PLATE II

1. Thickening and galling caused by stem eelworm infesting sugar beet seedlings grown in soil inoculated with crown canker material.

2. Typical distorted and multiple crowned sugar beet plant infested with stem eelworm.
Norwich, June 1953.

3. Severe crown canker in sugar beet caused by stem eelworm.
Ely, November 1953.

PLATE III



Tuber with normal sprout and sprout affected by *Spongospora subterranea*, causing a lateral gall. (*Variety :* Home Guard.)
Above : Longitudinal section through affected sprout.

PLATE IV

GALLS ON POTATO SPROUTS CAUSED BY *SPONGOSPORA SUBTERRANEA*

by R. K. McKee

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Since infection of sprouts on seed tubers by *Spongospora subterranea* (Walbr.) Lagerh. was mentioned by Pethybridge (1910), instances of galls on this part of the plant have been noted from time to time. A particularly interesting case came to our attention in 1954 in a stock of Home Guard. Three hundredweights of seed tubers of this variety, grown in Northern Ireland by the National Institute of Agricultural Botany for clonal trials, were put out in chitting trays at Sutton Bonington on November 2, 1953. Most of the tubers had sprouted by January 15, 1954, and on examination of all the tubers at that time, eleven were found to have galled sprouts. These tubers were all in upper trays which had been moistened from time to time by a slight penetration of rain through the roof ventilators.

Growth of the infected sprouts had been stimulated and they were much longer than the healthy sprouts. There was little indication of powdery scab lesions on any of the entire stock of tubers. No reports have been received of galls on the samples of the same stocks sent to other N.I.A.B. trial centres, nor on the bulk lots of these stocks retained in Northern Ireland.

The galls (Plate IV) consisted of lateral swellings on the sprouts, ranging in width from about 0·3 to 1·3 cm. The lateral origin was evident in the smaller galls, but continued growth of the diseased tissues in some of the larger galls had caused such distortion that only the tip of the sprout was recognizable. The surface of the galls was at first white and smooth, in sharp contrast to the coloured hairy surface of the sprouts. With increasing age, the galls became fawn in colour, with pale purple patches ; growth cracks developed and eventually necrosis of the tissues occurred, extending inwards from the surface.

Examination of sections of the galls (Plate IV) showed that the tissues, apart from a few scattered vascular strands, consisted of parenchymatous cells and that the majority of these were infected by *S. subterranea.* It was noticeable, however, that infection was confined to compact zones separated from one another by narrow bands of uninfected tissue, the lines of demarcation being very sharp. Each zone of infected cells was more or less cylindrical in shape and extended radially outwards from a region near the vascular tissues of the sprout, the shape becoming irregular near the surface of the gall. The smallest and most heavily stained cells in each infected zone were those at the inside border ; here, the parasite was present in the plasmodial stage, while spore balls had been formed in the cells nearer the surface. The general appearance suggested that the infected zones had arisen from meristematic tissues near the pericycle and, in origin, might be considered as homologous with the initials of adventitious roots. Considerable numbers of such roots were formed in nearby uninfected parts of the sprouts. Root gall tissues have been shown (Piard-Douchez, 1949) to result largely from hyperplasy of cambial cells of the root ; in the sprout galls it appears possible that the apical meristems of the adventitious roots were involved. The cells of these galls, whether infected or uninfected, did not differ

greatly in size from parenchymatous cells in healthy regions, indicating that the gall formation was due to hyperplasia. This was not restricted to the infected zones but occurred also in the adjacent, uninfected tissues.

It seems probable that infection of the sprouts occurred at some time after boxing, when the tubers were moist owing to rain leakage. The absence of typical powdery scab lesions on the tubers would appear to indicate that the infection did not take place during the growing season. Melhus, Rosenbaum and Schultz (1916) have noted, however, that galls due to *S. subterranea* may sometimes be very numerous on potato roots while the tubers remain absolutely free from infection.

Thanks are due to Mr. P. T. G. Twiss for the photographs.

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EXPERIMENTS ON THE CONTROL OF CARROT FLY ON CELERY

by J. D. THOMAS AND W. J. BEVAN

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It is well known that the larvae of the Carrot fly, *Psila rosae* F., attack not only carrots, but also celery, parsnips and parsley. In areas such as the moss lands of Lancashire, where celery is grown on an extensive scale, the insect is a serious pest in some years.

The soil of the moss lands is black peat overlying raw brown peat many feet thick, and for well over fifty years celery has been one of the main crops grown on it. At one time it was common practice to intercrop the celery with early carrots for bunching in July. Most growers now favour lettuce as the associate crop, and this is cut as it becomes marketable, so that the soil between the drills is cleared for the earthing up of the celery. The celery is sown in cold frames in February and planted out into drills about six feet apart during the latter part of May.

Young Carrot fly larvae may be found burrowing in the crown, roots and bases of the leaf stalks from mid-June onwards. By the middle of July the attacked crops begin to show obvious symptoms of root trouble, the plants make uneven growth, and there is a variable amount of yellowing of the leaves. These symptoms are accentuated by drought, but in showery weather they may be partly masked by the capacity of the plant to make new growth. Towards the end of July the larvae may be present in such numbers that almost the whole

of the crown and larger roots are reduced to a dark brown rotting mass. The crop often recovers its green colour and makes some new growth by late September. Severely attacked plants remain small throughout the season, and before marketing require drastic trimming to remove the damaged outer leaf stalks, the resulting sticks being of poor size and quality.

TRIAL IN 1951

In 1951 at Hundred End in Lancashire, a trial was made of " dipping " and " drenching " treatments for the control of the fly. In the dipping method, batches of 50 plants were immersed in suspensions of insecticides to cover the roots and lower parts of the stems with a thin deposit of the insecticidal material before planting out. In the drenching method less concentrated suspensions were made up and poured around each plant soon after planting out, at the rate of ¼ pint per plant. The dips tried were : 1 lb. of 4 per cent calomel dust in 3 pints of water (about 1 per cent calomel) ; 1 oz. of 35 per cent toxaphene wettable powder in 1¼ pints of water (1·4 per cent toxaphene) ; 1 lb. of " taint-free " BHC wireworm dust in 3 pints of water (about 1 per cent BHC) ; and 1 oz. of 25 per cent *gamma*-BHC wettable powder in 1¼ pints of water (1 per cent *gamma*-BHC). The drenches were 8 cc. of 50 per cent miscible toxaphene emulsion per gallon of water (0·09 per cent toxaphene) ; and ⅛ oz. of 25 per cent *gamma*-BHC wettable powder per gallon of water (0·05 per cent *gamma*-BHC). There were four replications of each treatment and control in a randomized block layout, each plot consisting of a single row of 50 plants, spaced seven inches apart. The trial was in a large field of Late Pink celery intercropped with early carrots for bunching. The dipping was done before planting out on May 22, and the drenching on the same day immediately after planting. The trial area was surrounded by untreated crop.

TABLE 1

EFFECT OF DIPPING AND DRENCHING TREATMENTS ON INCIDENCE OF CARROT FLY DAMAGE AND TOTAL WEIGHT OF CELERY PLANTS, 1951

(Weights and gradings are for 40-plant samples)

Treatment	August 20, 1951				October 3, 1951				January 14, 1952
	Grading for Damage by Carrot fly			Total Weight	Grading for Damage by Carrot fly			Total Weight	Total Weight*
	Free	*Slight*	*Severe*	*oz.*	*Free*	*Slight*	*Severe*	*oz.*	*oz.*
Calomel Dip (1%)	1	20	19	337	0	16	24	765	847
Toxaphene Dip (1·4%) ..	0	13	27	327	0	10	30	725	774
Drench (0·09%) ..	12	28	0	522	0	30	10	1,152	1,096
BHC Dip (1%)	0	20	20	409	0	20	20	744	815
Gamma-BHC Dip (1·0%) ..	13	26	1	484	0	24	16	963	950
Drench (0·05%) ..	27	13	0	597	29	11	0	1,473	1,240
Control Untreated.. ..	1	24	15	337	0	20	20	719	810
Significant Difference (P = 0·05)				153				294	262

*After trimming for market ; other weights are for whole plants after removal of roots.

Observations made during the growing season revealed no differences in growth between the plants in the various plots up to mid-July. By the first week of August, however, the plants treated with the *gamma*-BHC and toxaphene

drenches appeared larger and healthier than the controls. The plants which had been treated with the *gamma*-BHC dip also appeared more vigorous, but here the effect was not so pronounced. The plants in all the other plots were stunted and showed yellowing of the leaves. The plants treated with *gamma*-BHC drench appeared to maintain their lead in growth to the end of the season, but during October and later those treated with the toxaphene drench and the *gamma*-BHC dip became less easy to distinguish from plants treated in other ways.

Random samples of 10 plants from each plot were taken three times during the season—on August 20, 1951, October 3, 1951, and January 14, 1952. On the first two occasions the samples were brought back to the laboratory, where the roots were washed and the plants were graded by eye according to the amount of damage sustained by the roots and crowns. The categories used were: " Free ", for plants on which the roots and crowns were not marked in any way by Carrot fly larvae ; " Slight ", where there were not more than six small burrowed areas ; and " Severe ", where there was considerable damage to roots and crowns. The plants were then weighed after removal of the roots. The weights of the plants (Table 1) give a good indication of the extent to which growth had been checked as a result of Carrot fly attack.

The results (Table 1) show that in the 1951 trial the calomel dip was ineffective, and the BHC and toxaphene dips gave negligible control, possibly because there was an insufficient amount of the insecticide present. Dipping in the 1 per cent *gamma*-BHC suspension gave promising results ; but drenching the soil round the plants with *gamma*-BHC and toxaphene were the only treatments which gave sufficiently good control to result in a significant increase in the weight of the plants.

TRIALS IN 1952

As the process of applying ¼ pint of liquid to each plant by the drenching method is laborious, and large quantities of water would be required for its application on a field scale, trials in 1952 were directed to possible improvement of the dipping treatment by increasing the strength of the suspension used, and to the substitution of spraying for drenching. In the spraying treatment a knapsack sprayer was used to apply the insecticidal suspension to the surface soil in a narrow band not more than four inches wide along the rows of plants—a method of application that could also be effected by using a spraying machine with the nozzles set low and spaced to suit the rows.

The treatments in 1952 were a 4 per cent *gamma*-BHC dip (4 oz. of 25 per cent *gamma*-BHC wettable powder in 1¼ pints of water) ; 0·05 and 0·025 per cent *gamma*-BHC drenches (made up from ⅓ and ⅙ oz. of the same powder per gallon of water, and applied at ¼ pint per plant) ; 0·7 and 0·35 per cent *gamma*-BHC sprays (made up from 2 oz. and 1 oz. of the powder in 3½ pints of water, applied at about 10 c.c. per plant) ; and a 2·5 per cent toxaphene spray (100 c.c. of 50 per cent miscible toxaphene emulsion in 3½ pints of water, applied at about 10 c.c. per plant). There were four replications of each treatment and control in a randomized block layout, each plot consisting of a single row of 50 plants at seven-inch spacing. The rows were six feet apart and interplanted with lettuce. Planting and all treatments were carried out on May 20, 1952.

Little or no difference could be seen between the plants in the various plots until early August, when those treated with the *gamma*-BHC drenches and the *gamma*-BHC dip appeared healthy and were making rapid growth. The spray-treated plants were making moderate growth, but were distinctly better than the

untreated plants, which were poor. These differences in size of plants were maintained relatively for the rest of the growing season. Random samples of 10 plants were taken from each plot on October 10, 1952, and December 18, 1952. The roots were examined as in the previous year. The results are given in Table 2.

TABLE 2

EFFECT OF DIPPING, DRENCHING AND SPRAYING TREATMENTS ON INCIDENCE OF CARROT FLY DAMAGE AND TOTAL WEIGHT OF CELERY PLANTS, 1952

(Weights and gradings are for 40-plant samples)

Treatment	October 10, 1952				December 18, 1952
	Grading for Damage by Carrot Fly			Total Weight	Total Weight*
	Free	*Slight*	*Severe*	*oz.*	*oz.*
Gamma-BHC					
Dip (4·0%)	8	31	1	837	1,524
Drench (0·05%)	11	28	1	1,155	1,828
Drench (0·025%)	16	24	0	842	1,664
Spray (0·7%)	7	32	1	634	1,408
Spray (0·35%)	6	32	2	659	1,472
Toxaphene					
Spray (2·5%)	1	32	7	613	1,392
Control					
Untreated	0	12	28	435	1,180
Significant Difference (P = 0·05)				188	

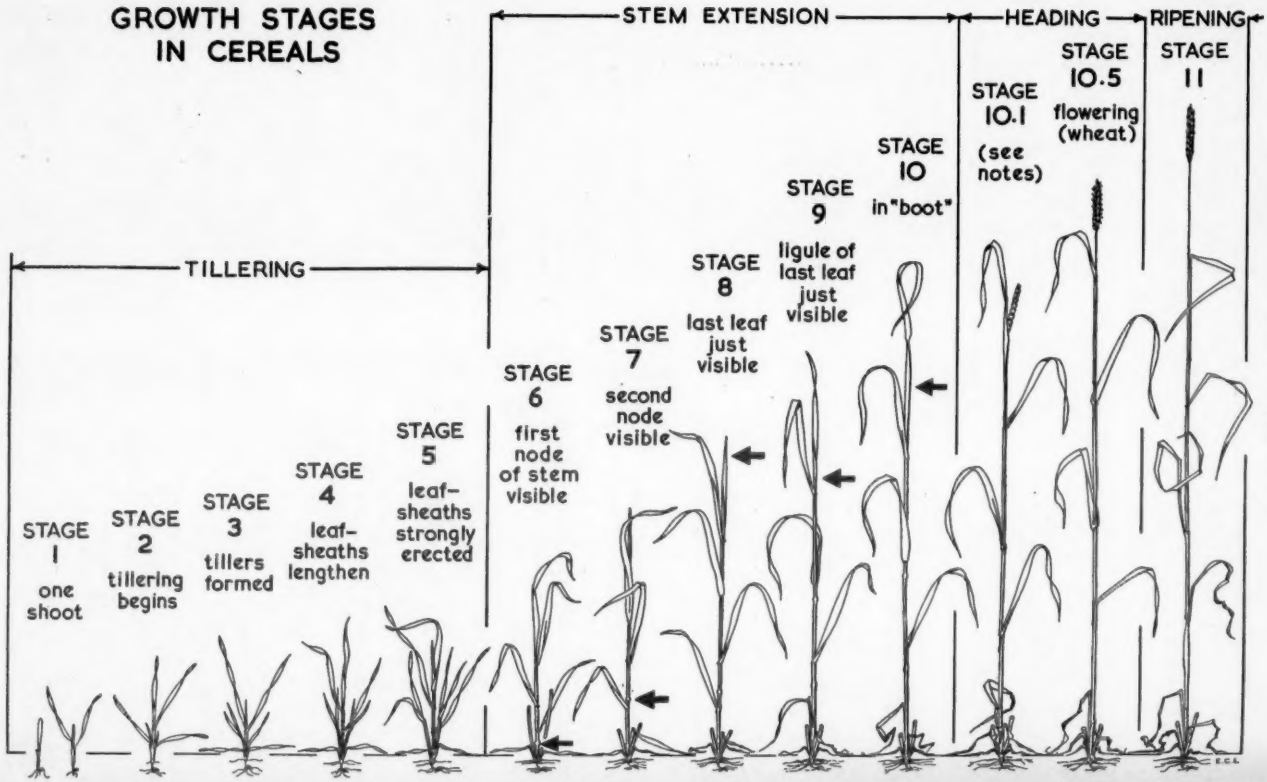
*Weights are for whole plants after the roots only had been trimmed off.

The weights of the plants given in Table 2 do not reflect adequately the marked differences in the quality of the plants from the various treatments. The celery treated with *gamma*-BHC as a drench or dip was of very good quality and much superior to that treated in any other way. The celery treated with *gamma*-BHC as a spray was of fairly good quality, while that from the toxaphene and other plots was poor.

The results indicate that the 0·025 per cent *gamma*-BHC drench did not give such good control as the 0·05 per cent drench. The two spray treatments with *gamma*-BHC were designed to apply the same amount of material per plant as the two drenches. The differing results obtained were therefore presumably due to the different methods of application. When applied as a drench, the insecticide would be carried down to a depth of an inch or two below the surface of the soil around the plant. The spray, however, would tend to deposit the insecticide entirely on the surface of the soil, where it would be subject to greater losses from exposure. Stirring the surface soil for the removal of seedling weeds would also tend to remove some insecticide from around the plant.

The dip method of applying *gamma*-BHC used in 1952 gave a fairly good degree of control ; and it was also the most practicable and economical of the methods tried. No phytotoxic effects were observed as a result of any of the treatments in 1951 and 1952. But in a similar trial in 1953, when planting out was followed by dry weather, plants subjected to the dipping treatment suffered an early check, although they later grew out of it.

Thanks are due to Mr. J. Blundell of Station Farm, Hundred End, Lancs, and to Mr. C. Johnson of Woodlands Farm, Cadishead, Lancs, for permission to carry out these trials on their crops in 1951 and 1952, respectively ; and to Mr. J. W. Ewan and the horticultural staff of the N.A.A.S. in Lancashire, for assistance with the field work.


GROWTH STAGES
IN CEREALS
STEM EXTENSION
HEADING
RIPENING
TILLERING
STAGE 1
one shoot
STAGE 2
tillering begins
STAGE 3
tillers formed
STAGE 4
leaf-sheaths lengthen
STAGE 5
leaf-sheaths strongly erected
STAGE 6
first node of stem visible
STAGE 7
second node visible
STAGE 8
last leaf just visible
STAGE 9
ligule of last leaf just visible
STAGE 10
in "boot"
STAGE 10.1
(see notes)
STAGE 10.5
flowering (wheat)
STAGE 11

GROWTH STAGES IN CEREALS

ILLUSTRATION OF THE FEEKES SCALE

by E. C. LARGE

Plant Pathology Laboratory, Harpenden

The following scale, essentially that originally provided for wheat by Feekes (1941) but with some additional notes by the late Dr. F. Earnshaw of the National Institute of Agricultural Botany, and with my illustrations from plants in the field, has been used extensively in advisory and investigational work on cereals in England and Wales during the past four years. With variations (as noted) in the heading stages, the scale has been found applicable not only to wheat, but also to oats, barley and rye. It is in use for defining the course of growth of cereal crops in relation to seasonal conditions and variety; for indicating the stage of development of the plants when mildew, rust and other disease and pest assessments are made; and also in connection with work on growth-regulator weed-killers, where the risk of damage to cereals is crucially dependent on the stage of growth at which the material is applied. The diagram has now been redrawn (p. 128), with reference to further detailed scale drawings of all four cereals from emergence to harvest made at the Plant Pathology Laboratory during the past three seasons.

Stage		
1	One shoot (number of leaves can be added) = " brairding "	TILLERING
2	Beginning of tillering	
3	Tillers formed, leaves often twisted spirally. In some varieties of winter wheats, plants may be " creeping " or prostrate	
4	Beginning of the erection of the pseudo-stem, leaf sheaths beginning to lengthen	
5	Pseudo-stem (formed by sheaths of leaves) strongly erected	
6	First node of stem visible at base of shoot	STEM EXTENSION
7	Second node of stem formed, next-to-last leaf just visible	
8	Last leaf visible, but still rolled up, ear beginning to swell	
9	Ligule of last leaf just visible	
10	Sheath of last leaf completely grown out, ear swollen but not yet visible	
10.1	First ears just visible (awns just showing in barley, ear escaping through split of sheath in wheat or oats)	HEADING
	10.2 Quarter of heading process completed	
	10.3 Half of heading process completed	
	10.4 Three-quarters of heading process completed	
	10.5 All ears out of sheath	
	10.5.1 Beginning of flowering (wheat)	FLOWERING (WHEAT)
	10.5.2 Flowering complete to top of ear	
	10.5.3 Flowering over at base of ear	
	10.5.4 Flowering over, kernel watery ripe	
11.1	Milky ripe	RIPENING
11.2	Mealy ripe, contents of kernel soft but dry	
11.3	Kernel hard (difficult to divide by thumb-nail)	
11.4	Ripe for cutting. Straw dead	

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SUGAR BEET YELLOWS IN GREAT BRITAIN, 1953

by R. HULL

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Virus Yellows developed slowly in sugar beet in 1953. Counts in sample fields made by the agricultural staff of the British Sugar Corporation gave 0·05 per cent of the plants infected at the end of June, and 2·0, 6·1 and 12·7 per cent at the end of July, August and September respectively. An independent estimate, based on the acreage carrying varying proportions of infected plants, gave an average of 8·1 per cent infected plants at the end of August. This incidence of Yellows resembled that in 1942, 1946 and 1951, when the disease caused little loss. The actual yields and calculated losses for 1953, presented in the same form as those for 1945–52 (Hull, *Plant Pathology*, **2**, 39–43), were as follows :

Calculated Percentage Loss of Sugar Yield		Actual Yield per acre		Estimated Potential Yield of Roots* per acre	Estimated Loss of Root Yield*
A–B†	C†	Sugar	Roots*		
		tons	*tons*	*tons*	*tons* (000)
2·9	4·4	2·14	13·36	13·76	158

*Converted to equivalent yields at a sugar content of 16 per cent.

†A–B. Assuming 4½ per cent loss for each week infected. C. Assuming 2·4 cwt. loss for each 10 per cent infection at the end of August.

The calculated average loss of yield in 1953 was 0·39 tons per acre of roots. Although the actual yield in 1953 was a record for the country, this calculation suggests that the season was potentially not quite so favourable for growth of sugar beet as 1950, when Yellows caused greater loss. The actual yield in 1950 was 13·23‡ tons per acre at 16 per cent sugar content, but the potential yield was 14·01 tons per acre.

The disease was more uniformly distributed than usual. Only small areas in the east and west midlands and the south had crops with more than 20 per cent plants infected. The incidence was smallest throughout the midlands, parts of the south and Yorkshire, and in Scotland, where the average percentage of infected plants was less than 1, except in small areas along the Firth of Forth, where from 1 to 20 per cent had Yellows.

Unfavourable weather for aphid flight during May and June was probably responsible for the slow increase of infected plants. At the end of June in many districts *Myzus persicae* occurred predominantly on plants with Yellows ; there were few on healthy plants. In the middle of July counts made in each of 415 fields on five plants with Yellows and on twenty-five nearby healthy plants showed that, whereas the average number of *M. persicae* on five infected plants was 21·0, on five healthy plants it was only 4·3. By the end of July the infestation of *M. persicae* was the highest recorded since surveys were started in 1946. The infestation was too late to spread Yellows widely in the then rapidly growing root crop, but steckling beds sown in July in the east of England, except round Bedford, became heavily infested with winged *M. persicae* in early August, and later many of the plants developed Yellows.

‡This figure was misprinted in *Plant Pathology*, **2**, 42, 1953 as 12·23 tons.

METHODS FOR STUDYING THE SUSCEPTIBILITY OF POTATO FOLIAGE TO *PHYTOPHTHORA INFESTANS*

by MARGARET A. KEAY

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A problem encountered in breeding for resistance to disease is to devise a satisfactory method for inoculating the host plant with the parasite. The breeder must be sure that plants remaining uninfected are really resistant and that they have not merely escaped infection. At the same time, the method must not be so severe in its effects as to impair the vigour of the resistant plants. Two essentials are an adequate supply of inoculum and an efficient means of applying it. In many diseases there is also the problem of keeping the plants in a humid atmosphere following inoculation. It is during this phase that the general well-being of the resistant plants may be adversely affected. Lastly, the equipment used generally needs to be as simple as possible. The methods described below are those used at the Potato Genetics Station for testing the reactions of potato seedlings to *Phytophthora infestans* (Mont.) de Bary.

SOURCE OF INOCULUM

Abundant sporangia for inoculations are obtained by growing *P. infestans* on potato leaves kept in the dishes described below. Specialized strains are grown on leaves of the appropriate differential host. These cultures require sub-culturing every four to seven days. Stock pedigree cultures are kept by inoculating whole potato tubers, which are then stored at 5° C., and also by culturing the fungus on chick-pea agar (Keay 1953).

The inoculum is prepared by dipping into distilled water leaves on which the fungus is sporing. A second crop of sporangia often develops if the leaves are returned to a damp atmosphere for another 24 hours.

INOCULATION OF SEEDLINGS

The potato seedlings, growing in seed boxes, are inoculated by spraying them with a suspension of sporangia by means of an atomizer of the throat-spray type. The inoculation is made late in the afternoon, when the temperature is beginning to fall, and the boxes of seedlings are then kept for about 15 hours in a humidity chamber of the type described below. During the next day the plants are exposed to normal atmospheric conditions by removing the top part of the humidity chamber. In the late afternoon the plants are inoculated for a second time and returned to the humid atmosphere overnight. On the morning following the second spraying, they are moved to a shaded part of a glasshouse. After two to five days, depending on weather conditions, the first symptoms of infection appear. The seedlings are then replaced in a humidity chamber and the fungus begins to spore on susceptible plants within 24 hours. Susceptible seedlings are removed each day and destroyed. The seed boxes remain in the chamber until no further sporulation has been observed over a 24-hour period ; the total period is seldom longer than three or four days.

INOCULATION OF LARGER PLANTS

The task of inoculating larger plants by means of an atomizer of the throat-spray type is a laborious one, and such inoculations are frequently ineffective. However, consistently good infection has been obtained by using an Aerocide

projector (Pan-Britannica Industries, Ltd.), from which the inoculum is forcibly expelled by means of the compressed gas in a " sparklet bulb ". The hole in the standard nozzle has been slightly enlarged and 60–80 ml. of inoculum is applied per " sparklet ". The very fine mist from the projector gives excellent coverage and, by the force with which it is applied, thoroughly wets the leaves. The projector is sterilized after use by immersion in boiling water.

HUMIDITY CHAMBERS

The humidity chambers are made by covering wooden frames with " Alkathene " film (Stanton, 1951) and standing them with the bases in zinc trays containing water. These covered frames are efficient, hard-wearing, light to handle and easily cleaned. Boxes of seedlings put in these chambers are raised on blocks above water level to prevent the soil becoming waterlogged. Inoculations with the Aerocide projector are done inside the chamber ; the hand holding the projector is inserted through a hole made by raising a piece of the Alkathene film at one corner of the frame.

DETACHED LEAFLET METHOD

In genetical studies, and in breeding, information may be needed about the reactions of first-year seedlings to several strains of *P. infestans*. Resort is then made to the detached leaflet method, which may also be used with differential hosts for the rapid identification of strains of the parasite. The method is also valuable when dealing with non-indigenous strains of the fungus, as the danger of their spreading is reduced to a minimum.

Our standard technique is as follows : cellulose wadding is put in the bottom of an enamel pie-dish, wetted and covered with a sheet of blotting paper. The dish is then covered with surgical gauze, which is held in position by wetting the area in contact with the rim. The gauze sags a little and the leaflets, cut from the plants with clean razor blades, are placed on it, lower surface uppermost. The whole is then covered with a sheet of glass lined with wet blotting paper. Replicate leaflets are put in different dishes, and leaflets of known reaction in each dish serve as controls. Before the glass covers are put on, the leaflets are sprayed with a suspension of sporangia by means of an atomizer of the throat-spray type. Twenty-four hours later, the leaflets are turned over so that surplus moisture does not remain on the surface. Leaflets are always handled by means of sterilized forceps. The dishes are stacked in a closed box, ideally at 16–18° C., while the fungus is developing. The reactions of the leaflets are then determined by examining them under a binocular microscope.

This method has been found to give satisfactory results for testing leaf reaction to *P. infestans*, bacterial rots being reduced to a minimum and resistant leaves often remaining fresh for periods of two weeks or more. It has been found to be quite useless for studying reactions to *Alternaria solani*, but recently has been successfully used by Mr. R. Leach (*in lit.*) in studies on Chocolate Spot (*Botrytis fabae*) of beans.

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BEET STEM EELWORM

by R. A. DUNNING

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Crown canker of sugar beet, caused by stem eelworm, *Ditylenchus dipsaci* (Kühn) Filipjev, was first recorded in England by Roebuck and Hull (1937), although Goodey (1929) had noted it on mangolds as early as 1927. Severe damage is known to occur in parts of Switzerland, but this is reported to be due to *D. destructor* (Savary, 1953). Johnson (1939) described and figured distorted mangold seedlings that had been grown in cylinders containing rhubarb material infested with *D. dipsaci*. He stated that the infection failed to persist. Until 1953, only autumn crown canker had been noted in the field but, in that year, I observed the early symptoms of stem eelworm attack in seedling beet from fields in the Norwich area and elsewhere. Plants showing similar symptoms had been noted in the West Midlands in 1948, but the true cause was not discovered at the time.

Stem eelworm damage may first become evident when the beet is in the cotyledon or first " rough-leaf " stage. The petioles become thickened, distorted, and often galled (Plate III, 1) ; the plant eventually " grows away " from this type of attack, which was first found in the field in 1954*. More serious damage occurs when very early invasion under cool, moist conditions is combined with slow growth of the beet, leading to death of the main growing point, and thickening and distortion of the outer leaves. The axillary buds then develop to give a multiple-crowned condition in which the new growth is also thickened and distorted, with elongated leaf laminae (Plate III, 2). In such plants the stem eelworms are to be found at the base of the affected petioles, but are rarely numerous. This type of damage was prevalent in the field in 1948 and 1953. Although fresh healthy growth is eventually produced during the summer, the " multiple crown " and stunted appearance remain evident throughout the growing season. " Multiple crown " in beet may also be caused by *gamma*-BHC poisoning, mechanical damage, or insect injury. *Gamma*-BHC poisoning and hormone spray damage also produce other forms of distortion.

In the late summer and autumn of 1953, crown canker developed on beet in the fields that had been infested in early summer, but mainly on the larger, single-crowned beet. There may have been two separate and independent attacks*, but there is no doubt that both were caused by *D. dipsaci* (confirmed by Dr. J. B. Goodey in June and October). Roebuck and Hull (1937) described the symptoms of eelworm canker (Plate III, 3), which are similar in some respects to those of boron deficiency.

In the spring of 1954 the following plants became infested and showed typical symptoms (the first four as Plate III, 1) when grown on a plot into which cankered beet crowns had been dug in November 1953 : sugar beet, fodder beet, red beet, mangolds, oats, rye, onions, peas, beans, sainfoin, kidney vetch, alsike, chickweed (*Stellaria media*), and common orache (*Atriplex patula*). Other tests showed that beet seedlings became infested when grown in soil containing dried, infested oat, onion or beet material, again giving typical symptoms.

None of the 1953 attacks, either in the summer or autumn, could definitely be attributed to previous infestations in host crop plants. Nevertheless, the

* Observations during summer and autumn 1954 have shown that eelworms are capable of surviving in the withered petioles and leaf-scar tissue following damage of the type shown in Plate III, 1. Then from August onwards, the eelworms multiply rapidly and give rise to the autumn crown canker, which begins in the region of the lowest leaf scars.

infestation was probably already present in the fields and early sowing, combined with the cool, wet conditions in April, led to the relatively widespread attacks. In 1954, infested and multiple-crowned beet were found in a field where onions had been attacked by stem eelworm the previous year. The widespread nature of attacks in 1953 suggested that the eelworm might also be seedborne, but experimental work has so far given no definite proof.

The loss in yield due to " multiple crown " and canker was determined at two sites in 1953. " Multiple crown " alone was not serious, producing a loss of up to £3 14s. per acre. However, subsequent cankering, especially of the larger beet, produced an increased top tare at the first site and a reduced sugar percentage at the second. The overall loss from stem eelworm attack in spring and autumn at the levels observed was estimated at between £4 and £5 per acre (Dunning, 1954).

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OBSERVATIONS ON WHEAT BULB FLY INFESTATION OF BROADBALK WHEAT PLOTS

by F. RAW

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Wheat Bulb fly, *Hylemyia coarctata* Fall., has been observed to infest the Broadbalk wheat plots at Rothamsted in varying degree since a system of fallowing was introduced in 1925 to control weeds. The Broadbalk experiment (Russell and Watson, 1940) offers a unique opportunity for studying some aspects of Wheat Bulb fly infestation, for it provides continuous wheat and a fallow on plots of widely different fertility, but on the same soil type and with the same climate. Observations were begun in 1953 to determine whether the level of infestation differed on different plots and, if so, to what factors the differences could be related.

The Broadbalk plots, which are long parallel strips, each of $\frac{1}{8}$ acre, separated by pathways, receive their respective manurial treatments annually for each wheat crop grown. When fallowing was introduced, the field was divided across the plots into five equal sections, one section being fallowed each year and cultivated at intervals to eradicate weeds. Five plots (Nos. 2, 3, 5, 8 and 10)

were selected for study, each representing a different manurial treatment, as shown in Table 1. Within these plots, two of the sections (Nos. 2 and 5) were studied. Section 2 was fallowed in 1952 and Section 5 in 1953, so that at the time the observations were made (December 1953 to March 1954) Section 2 was carrying the second crop after fallow and Section 5 the first crop after fallow.

METHODS

The infestation was measured in two ways. First, the population of eggs in the soil was estimated in the winter, and secondly the population of larvae in the plants was estimated in the spring.

Egg Population. To estimate the egg population just before hatching, ten soil samples were taken on December 19, 1953, from each section of the five plots. Each sample consisted of two cylinders of soil each 2½ inches diameter and 9 inches deep, taken one yard apart. These composite samples were taken to reduce the variability. The eggs were extracted by a standard wireworm flotation method.

Larval Population. To estimate the larval population ten plant samples were taken on March 29, 1954, from each section of the five plots. Each sample consisted of the plants from a 6 inch length of two adjacent rows. All the shoots were dissected and the numbers of plants, shoots, infested shoots and larvae were recorded for each sample. At the time of sampling, most of the plants on the plots with adequate nutrient had 4–5 tillers, but the internodes had not begun to elongate. The wheat variety was Squarehead's Master (13/4).

RESULTS

Of the eggs recovered from the soil samples, 75 per cent came from Section 5. The egg counts from Section 2 varied greatly, and when the plant samples from this section were examined, few of the shoots were found to be infested. Beyond confirming that the infestation was almost confined to the first crop after fallow, the data from Section 2 yield little information and have been omitted. The data for Section 5 are summarized with other relevant information below.

TABLE 1

SUMMARY OF DATA FOR SECTION 5—FIRST YEAR AFTER FALLOW

	Plot 2	Plot 3	Plot 5	Plot 8	Plot 10
Manurial treatment	Dung	None	P, K, Na, Mg	N_3, P, K, Na, Mg	N_2
Mean yield, 1949–52 (cwt. per acre)	19·4	9·4	10·2	18·8	14·2
December 1953					
Eggs per 98 square inches	67	41	42	45	84
Range	(2–14)	(0–9)	(0–11)	(0–14)	(0–26)
March 1954					
Plants per 10 feet of drill	234	209	220	302	243
Percentage infested	85·5	76·1	71·8	59·9	85·2
Number of shoots	1,264	582	1,033	1,149	639
Percentage infested	35·8	39·9	28·2	26·3	52·4
Number of larvae	329	159	222	241	242
Mean number of shoots per plant	5·4	2·8	4·7	3·8	2·6
Mean number of infested shoots per plant	1·9	1·1	1·3	1·0	1·4

Manurial treatments (per acre)

Dung = 14 tons
P = 3½ cwt. Superphosphate
N_2, N_3 = 4 cwt. or 6 cwt. Sulphate of Ammonia
K = 2 cwt. Sulphate of Potash
Na = 1 cwt. Sulphate of Soda
Mg = 1 cwt. Sulphate of Magnesia

Egg Population. The data have been analysed on a square root transformation. The plot means for the transformed data are :

Plot 2	Plot 3	Plot 5	Plot 8	Plot 10	Mean	Significant Difference (P = 0·05)
2·59	1·99	1·83	1·98	2·69	2·21	0·91

Standard error per plot 1·01, 45 d.f.

The differences between the plots are not significant. The precision of the experiments however is low, for the standard error per plot (1·01), is about 45 per cent of the experimental mean (2·21), because samples from the same plot differed greatly.

Larval Population. At the time the counts were made, most of the larvae were in the second instar, some were in the first, and a few were in the third. Exuviae were found in many shoots containing second instar larvae, and a very few shoots contained two larvae. The larval counts have been analysed on a square root transformation. The plot means for the transformed data in ranked order are :

	Plot 2	Plot 10	Plot 8	Plot 5	Plot 3	Mean	Significant Difference (P = 0·05)
	5·66	4·87	4·81	4·66	3·88	4·78	
Differences	0·79	0·06	0·15	0·78			0·81

Standard error per plot 0·90, 45 d.f.

The precision of the experiment is satisfactory, for the standard error per plot (0·90) is about 20 per cent of the experimental mean (4·78). There were significant differences between plots and we may consider that Plot 2 had a significantly greater larval population than Plots 10, 8 and 5, which in turn had a significantly greater population than Plot 3.

DISCUSSION

The differences between the egg populations of the plots are reasonably consistent with the differences between larval populations (Table 1). This suggests that the failure to detect significant differences in the egg populations may be due to the variability of the sampling data rather than to the absence of such differences. If such differences existed, they could arise from different levels of oviposition or from differential mortality of the eggs in the interval between oviposition and sampling. As the soil conditions of the plots seem to be more likely to affect oviposition than the survival of eggs, the second explanation seems the more probable.

The levels of infestation correspond to the fertility of the plots as reflected in their mean yields (Table 1), and hence to the amount of stubble ploughed back into the ground. The yields of straw at the harvest before fallowing (1952) were :

	Plot 2	Plot 3	Plot 5	Plot 8	Plot 10
Straw (cwt. per acre) ..	43·0	13·9	20·5	47·6	31·6

In addition, Plot 2 also contains the residues from dung applied at the rate of 14 tons per acre. If, during oviposition, Wheat Bulb flies are attracted to soil containing organic residues, this would account for Plot 2 having the highest infestation, Plot 3 the lowest, and Plots 5, 8, and 10 being intermediate. It is significant that Gough (1953) recorded that " in the Fens, heavier attacks usually, but not invariably, occur in the peaty rather than the silty areas if both soil types are present in the same field ". He also recorded (1947) that attacks may follow potatoes—a crop which often receives heavy dressings of organic manures—even when the ground is covered by foliage at the time of oviposition.

It can be seen from Table 1 that the larval counts are correlated with the numbers of shoots per plot. If the data from all fifty plant samples are pooled, there is a significant correlation between the numbers of larvae and the numbers of shoots per sample. ($r = 0{\cdot}653$, 0·1 per cent value for 48 d.f. $= 0{\cdot}45$). There is also a significant correlation between the numbers of larvae and numbers of plants per sample. ($r. = 0{\cdot}406$, 1 per cent value for 48 d.f. $= 0{\cdot}37$). These correlations suggest that the survival of newly-hatched larvae may be determined, at least in part, by the numbers of shoots available for infestation. Hitherto, the importance of the number of shoots has been emphasized only in so far as it relates to the ability of the crop to withstand attack, although Gough (1946) drew attention to the larval mortality which occurs when more than one larva enters a shoot.

The different numbers of shoots per plot can be attributed to the manurial treatments and the effect of the fallow. The principal effect of fallowing is to increase the available nitrogen supply. This effect was most pronounced on Plots 3 and 5, which got no nitrogenous fertilizers, and growth on these plots after fallow, at least in the early spring, was comparable to that on similar plots which were given nitrogen. Plots 3 and 10 are therefore comparable, and the few shoots reflect the lack of potash and phosphate in these plots. Similarly Plots 5 and 8, which were given the same mineral dressing, are comparable. Plot 2 had an adequate nutrient supply and, at the time of sampling, had rather more shoots than Plots 5 and 8.

Some indication of the effect of the infestation on the crop may be obtained by considering the average number of shoots and infested shoots per plant on the different plots (Table 1). The higher number of shoots per plant on Plot 2 offsets the higher infestation. The lower infestation on Plot 3 partly offsets the lower number of shoots per plant. Plot 10 appears to be most affected, and this plot has frequently given a lower yield in the first year after fallow than in subsequent years.

In 1936, there was a severe attack of Wheat Bulb fly on Broadbalk Section 3 (first year after fallow). A survey in May 1936 showed that whereas Plot 2 was not greatly harmed, Plots 5 and 8 were severely damaged, and Plots 3 and 10 were even worse (Evans, 1937). It was estimated that at harvest the yield of Plot 10 was reduced by about 80 per cent, and that of other plots by about 50–70 per cent, as compared with normal years.

The results so far obtained tentatively suggest that the intensity of Wheat Bulb fly attack is affected by the amount of organic residues in the soil and the density of shoots when the eggs hatch, but much further work on these aspects of the Wheat Bulb fly problem is required.

Mr. R. M. Dobson, Mr. J. R. Lofty and Mr. J. W. Stephenson helped to collect and examine the soil and plant samples. I am indebted to Dr. Mary Glynne and Dr. D. J. Watson for helpful discussions and information on the botanical aspects of the work, and to Mr. J. H. A. Dunwoody for help with the statistical analyses.

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CONTROL OF CHRYSANTHEMUM GALL MIDGE

by B. D. MORETON

National Agricultural Advisory Service, Wye

Chrysanthemum shoots heavily galled by *Diarthronomyia chrysanthemi* Ahlb. at Wye in 1952 were dipped in parathion and *gamma*-BHC suspensions and kept in a glasshouse with a minimum temperature of 43° F. The numbers of midges emerging in the 11-week period from the first treatment on December 3, 1952 to February 18, 1953—when the foliage was dying—were recorded. From three untreated shoots a total of 44 midges emerged (20 males and 24 females). Parathion was used at 0·01 and 0·025 per cent, both once (on December 3) and with a second treatment 17 days later, and no midges emerged from any of the three shoots for each treatment. *Gamma*-BHC in miscible formulation was used at 0·01 per cent with a second treatment 17 days later, and once at 0·02 per cent, and from each of the batches of cuttings which received these treatments one female emerged. At the end of the 11 weeks about 20 galls were examined after each treatment. With all the parathion series about 10 per cent of the galls contained dead larvae, and the remainder pupae which appeared to be lifeless. The majority of these pupae were abnormal with short wings and appendages. About 10 per cent of the galls on the *gamma*-BHC series contained dead larvae, with apparently lifeless pupae in the remainder, of which only a small proportion had abnormally shortened appendages. On the untreated shoots a few galls contained dead pupae, but the great majority were empty. No further emergences occurred in the following fortnight when the shoots were kept in the laboratory. Barnes (*Ann. appl. Biol.*, 1940, **27**, 71–91) gives the average period of egg to adult in mid-winter in a laboratory as 83 days, and it is thought that under the conditions of the present experiment there was sufficient time for the majority of adults to emerge. From this assumption and the behaviour of the untreated shoots it seems fair to conclude that both the parathion and *gamma*-BHC, even with a single thorough application, exerted a high degree of control. It would also appear that the insects in galls were mostly affected in the pupal instar ; at some time near this stage the galls tend to become thin walled at the apex, which may aid penetration by insecticides.

NEW OR UNCOMMON PLANT DISEASES AND PESTS IN ENGLAND AND WALES

Stem Eelworm on Wild White Clover. Some small plots of wild white clover at Cambridge were inspected in July 1949 for the presence of Stem eelworm, *Ditylenchus dipsaci* (Kühn). Slight infestations, which had caused little damage to the plants, were found on two of the plots. The main symptoms were swellings just below the flower-heads and on the leaf stalks. There was also some damage to a field crop in Lincolnshire in 1949, but there have been no subsequent records. A strain of Stem eelworm attacking wild white clover is well known on the Continent. The only previous published record for this country was on naturally-occurring wild white clover in Kent (Ware, W. M., *Ann. appl. Biol.*, 1925, **12**, 113–9).

E. B. BROWN.

Brown Rot Cankers in Merton Worcester Apple. During the autumn of 1953, Brown Rot cankers caused by *Sclerotinia fructigena* Aderh. & Ruhl. caused severe damage to fruiting spurs and to branches (Plate I), of the apple variety Merton Worcester in an orchard in Essex. The Merton Worcester had been frameworked three years previously on to established trees of Cox's Orange Pippin. The infection probably entered the branches through spurs that bore rotting fruits during the summer. The fruit crop was heavy and unthinned and showed a considerable amount of Brown Rot, possibly following damage by hail. The crop from the Cox trees in the same orchard was a little lighter but showed little Brown Rot, and there were no branch cankers. This type of branch infection by *S. fructigena* is not uncommon in some varieties, such as Laxton's Superb and James Grieve (*Rep. E. Malling Res. Sta. for 1944*, 1945, 124–6), but it is of interest to note the evident susceptibility of a new variety, Merton Worcester.

J. E. E. JENKINS AND M. H. MOORE

***Colletotrichum spinaciae* on Spinach seed.** A sample of Prickly Spinach (*Spinacia oleracea*) seed, harvested in 1953 from a crop grown in Lincolnshire, was found to be infected with *Colletotrichum spinaciae* Ell. & Halst. The original seed from which this crop was grown was produced in Holland. *C. spinaciae* has not before been identified with certainty in this country. A fungus tentatively identified as *C. spinaciae* was found by Mr. W. C. Moore on rounded spots on a few spinach leaves from Sussex in 1937, but the material was insufficient to justify publication as a new record. Tiny black acervuli, often so dense as appreciably to darken the seed, and bearing prominent setae, were present on a high proportion of seed coats in the sample I examined. Seeds bearing acervuli invariably gave rise to infected seedlings when germinated on a Copenhagen tank or in pans of sterile soil in a glasshouse, though only very few of the infected seeds failed to germinate. Most of the seedlings from seeds not visibly affected remained healthy. Symptoms appeared within a few days of seedling emergence in the pans. Either the seedlings became progressively brown at soil level, or colourless sunken lesions, which later bore acervuli, appeared higher up on the hypocotyl. In both cases collapse of the seedling occurred eventually. Cultures were obtained from pieces of infected hypocotyl and from spores taken from acervuli on damp seeds. Both in culture and on the seeds and seedlings the fungus agreed in morphological characters with those given by H. Schultz (*Zbl. Bakt. II*, 1939, **101**, 225–32), who made a detailed study of *C. spinaciae*, originally described by Ellis & Halstead (*J. Mycol.*, 1890–91, **6**, 34). The size of spores which I obtained from moist seeds ranged from 13·0—33·0 × 3·0—5·0μ (mean for 100 spores 24·8 × 3·5μ), while setae varied in length up to a maximum of 220μ. This fungus has previously been recorded in a number of European countries, including Holland, on the American continent, and in India, occasionally causing severe damage.

J. J. BAKER.

Stem and Bulb Eelworm on Potatoes. In June 1953, Mr. H. E. Shaw and Mr. A. E. Parkinson of the N.A.A.S. called our attention to a field of potatoes in Cheshire, mostly Home Guard but with a few Majestic, in which there were patches of stunted plants. In these patches the leaf bases and stems were swollen and distorted, with a bunched or tufted appearance around the growing points (Plate II, 2), and on some of the more severely affected plants brown lesions were visible, particularly at and just above ground level. The lesions often extended into the pith, causing internal breakdown. *Ditylenchus dipsaci* (Kühn) Filipjev was present in considerable numbers in the affected tissue. Dr. T. Goodey confirmed this diagnosis. This is the first record of Stem and

Bulb eelworm infestation on a crop of potatoes in this country, although Southey and Staniland (*J. Helminth.*, 1950, **24,** 145) described a similar attack on a volunteer potato plant growing among strawberries infested with *D. dipsaci*. Swedes growing next to the affected potatoes in Cheshire showed distortion and lesions. This damage was partly due to swede midge, but stem eelworm was also present in the plants. A number of the weeds, for example, corn sow thistle (*Sonchus arvenis*), corn mint (*Mentha arvensis*), scarlet pimpernel (*Anagallis arvensis*), and black bindweed (*Polygonum convolvulum*), were found to be harbouring stem eelworm. By August 7 most of the infested potato plants were dead and weeds had overgrown the field. The yield from the infested plants was reduced to a few small tubers per plant. No infestation was found in the tubers, although both Dr. J. B. Goodey and Mr. J. F. Southey have since obtained tuber infestation in pot experiments using our material as inoculum. From the farmer's description of the previous oat crop, which had had weak patches, it was suspected that the oat race of *D. dipsaci* was concerned. Pot tests, using the infested material as inoculum, failed to produce typical symptoms in oats but did cause lesions on runner beans. This bean material produced typical " tulip root " on oats in a second test.

The identity of the stem eelworm as an oat race was confirmed in 1954 by observations in the field. Wheat was sown over most of the affected part and oats on the rest of the field. The oats just overlapped the affected area, resulting in a narrow strip which showed well-developed tulip root symptoms. Volunteer potato plants in the same strip showed symptoms like those in the original crop. Undersown red clover showed poor growth in the affected area but was normal in the rest of the field. The clover did not show typical symptoms of stem eelworm attack, although *D. dipsaci* was recovered from it. T. Goodey (*J. Helminth*, 1941, **19,** 1) found similar damage to red clover in a " seeds " mixture exposed to the oat race of *D. dipsaci*.

H. C. F. NEWTON AND C. M. G. DUTHOIT.

Chrysanthemum Eelworm in Tomato Fruits and Callistephus. Two tomato fruits were received in September 1953 from a nursery growing about an acre of outdoor tomatoes at Mildenhall, Suffolk. When these tomatoes were cut in half a light brown decay was seen to be spreading into the fruit from the calyx. An examination of this tissue revealed the presence of Chrysanthemum eelworm, *Aphelenchoides ritzema-bosi* (Schwartz). When the nursery was visited an intensive search failed to reveal any leaf symptoms or any further infested fruits. No chrysanthemums were grown on the holding, but the annual aster (*Callistephus*) was grown on a considerable scale. This is known to be a host of Chrysanthemum eelworm, although infestations are seldom recorded. Infested plants exhibiting symptoms like those commonly seen on chrysanthemums were easily found. The lower leaves were dead and higher leaves showed a chlorosis of areas clearly demarcated by the veins. The only previous published record of attack by Chrysanthemum eelworm on tomato fruits was by Goodey and Bennet (*J. Helminth.*, 1941, **19,** 123–6). Here, also, the tomatoes were being grown outdoors and infested fruits were difficult to find.

E. B. BROWN.

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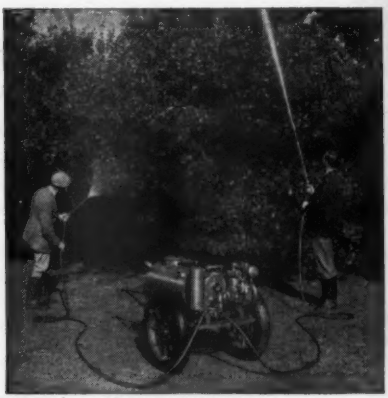

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